Age and growth of *Conger conger* (Congridae) from the north coast of Tunisia

by

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Abstract. – A total of 239 European conger eels, *Conger conger* (Linnaeus, 1758), were collected from the north coast of Tunisia between January 2011 and December 2012. Their lengths ranged between 23.8 and 136.0 cm and their weight between 17.26 and 5000.00 g. Their individual age, determined from vertebrae and sagittal otoliths, ranged from one to seven years; most of the sampled fish were between three and four years old. The length-weight relationship was determined as follows: $W_t = 0.0003TL^{3.37}$ (R = 0.987). The conger eel of the Tunisian north coast showed positive allometric growth (b = 3.37) and b values, which were significantly different from 3. The von Bertalanffy growth function for the sample population had the following parameters: $L_\infty = 249.032$ cm, $K = 0.118$ year^{-1} and $t_0 = 0.97$ year.

Résumé. – Âge et croissance de *Conger conger* (Congridae) de la côte nord de la Tunisie.

L'âge et la croissance du congre d'Europe (*Conger conger*) ont été déterminés à partir de 239 individus prélevés sur la côte nord de la Tunisie. La longueur totale des spécimens variait entre 23,8 et 136,0 cm et la masse totale entre 17,26 et 5000,00 g. L'âge a été déterminé à partir des otolithes et des vertèbres. Les *C. conger* échantillonnés étaient âgés de un à sept ans, avec une prédominance des classes d'âge trois et quatre ans. Les paramètres de l'équation de von Berttalanffy relatifs à la croissance en longueur de ces spécimens sont : $L_\infty = 249{,}032$ cm, $K = 0{,}118$ an^{-1} et $t_0 = 0{,}97$ an. La relation taille-masse est déterminée comme suit : $W_t = 0.0003Lt^{3.37}$. La valeur de la pente (b = 3,37) est significativement supérieure à 3, ce qui traduit une allométrie majorante.

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Key words
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The European conger eel, *Conger conger* (Linnaeus, 1758), is a widely distributed marine fish found in the North-eastern Atlantic. Its geographical range runs from Norway to Senegal, including the Canary Islands, the Azores, Madeira, the Mediterranean and the western Black Sea (Bauchot and Saldanha, 1986); consequently, it is an important commercially fished species (Morato *et al*., 1999; Relini *et al*., 1999; O'Sullivan *et al*., 2003).

Catches of *C. conger*, during the period from 2004 to 2014 showed inter-annual fluctuations. The maximum production was reached in 2014 with 81.68 tons. Particularly, on the north coast of Tunisia production of *C. conger* was increasing from the year 2012. However, nationally, the capture and exploitation of this species remain low and always less than 100 tons (Anonymous, 2004-2014).

Studying the age and growth of fish species allows us to determine the structure of the sampled population, and provide key elements to fishery management hoping to produce maximum sustainable yields (Jones, 1992). Similarly, it is a fundamental step in the study of a fish growth. The individual age estimation of osteichthyes is based on the deposited growth marks in the hard parts: the bones, the scales and the otoliths (Panfili *et al*., 2002). However, as the *C. conger* is a smooth skinned species with relatively few scales, we had to focus our study purely on the otoliths and the vertebrae.

Data on the age and growth of *C. conger* in the Atlantic Ocean has been documented by several authors (Sbaihi *et al*., 2001; O'Sullivan *et al*., 2003; Correia *et al*., 2009). Conversely, in the Mediterranean Sea, the age of the *C. conger* has only been studied in the Adriatic Sea by Vallisneri *et al*. (2007) and Matić-Skoko *et al*. (2012). And although several authors have reported the presence of *C. conger* along the north coast of Tunisia (Gruvel, 1926; Bourgeois and Farina, 1961; Azouz, 1971, 1974), no study on the age and growth of this species has yet been published.

MATERIALS AND METHODS

A total of 239 *C. conger* specimens captured between January 2011 and December 2012 off the north coast of Tunisia (Fig. 1), were used in this study. Their total length and body weight ranged from 23.8 cm to 136.0 cm and from 17.26 g to 5000.00 g, respectively. Specimens were collected

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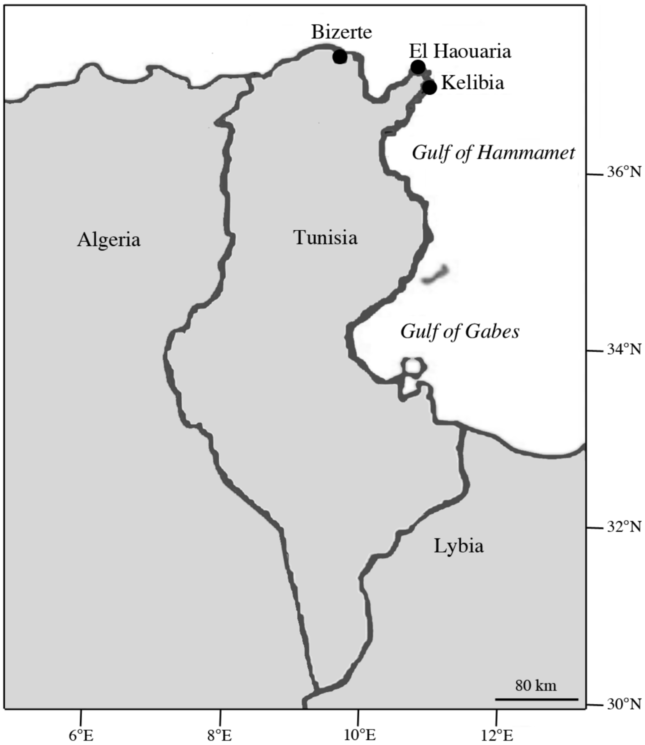

Figure 1. – Sample sites (•) on the north coast of Tunisia.

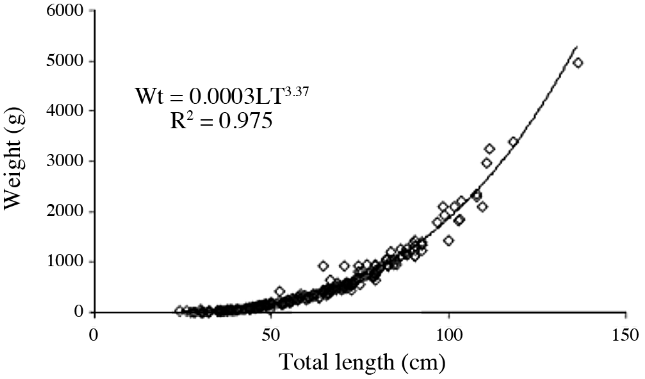

Figure 2. – Length-weight relationships of the European conger eel, *Conger conger*, from the north coast of Tunisia.

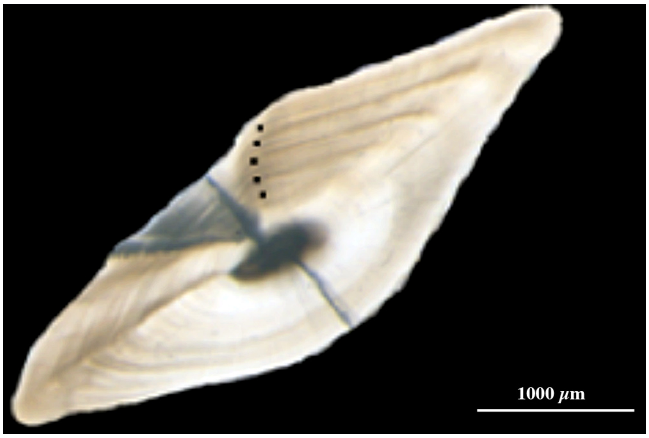

Figure 3. – Views of transverse section of an otolith of *Conger conger* observed with reflected light (×20). Otolith from a 995 mm-total length specimen (five annuli present).

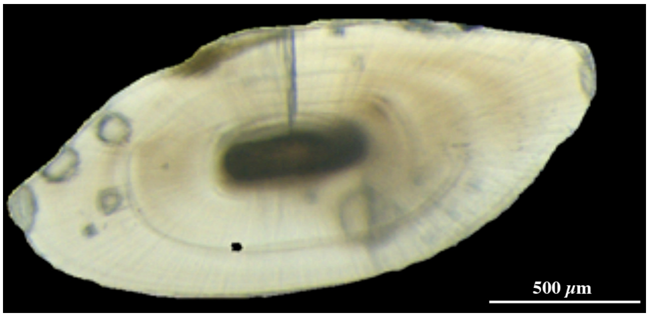

Figure 4. – Views of transverse section of an otolith observed with reflected light (×20). Otolith from a 238 mm-total length *Conger conger* (only one annulus present).

by trawl nets and longlines. Nets are dragged by a boat called trawler. Longline are operating at night and then raised the next morning.

For each individual, we identified the following two parameters: the total fish length in cm (Lt) and the total weight (Wt) in g. Otoliths were removed from otical capsules using fine forceps, cleaned under running water, dried at room temperature and stored for further study in Eppendorf tubes labelled with the fish number, date and site of capture.

The treatment of otoliths was performed at the otolithometry platform in the ichthyology laboratory of the Muséum national d'Histoire naturelle, Paris. Otoliths were embedded in a polyester resin, sectioned transversely through the nucleus, polished and mounted on glass microscope slides. A drop of essential rosemary oil was placed on the section to enhance the contrast of rings. Sections were examined for banding patterns under a binocular microscope (×20) with transmitted light, and their age was determined by counting the rings. All otolith sections were read independently by two researchers.

To enable sclerochronology, a single vertebra was removed from each fish: from the origin of the dorsal fin to above the tip of the pectoral fins. This area has been recognized as being preferential for examining growth rings (O'Sullivan *et al.*, 2003). After removal, the vertebrae were carefully cleaned of any adherent tissue, air-dried and stored. The vertebrae were then examined under a dissecting microscope with reflected light at a low magnification (×10). This technique allowed us to count the growth marks on each vertebra. For each vertebra, a double reading was used to check the number of growth marks.

To confirm the results of the otolith study, we used the vertebrae to estimate the individual age of the conger eels. If both calcified parts of the same fish were interpreted with the same number of growth marks, the verification was deemed complete (Wilson *et al.*, 1983).

To determine the onset period of the appearance of growth arrest rings, we analyzed the monthly changes in the marginal increment. The marginal increment was calculated as the distance between the outer edge of the last annulus and the edge of the otolith (Hood *et al.*, 1988; O'Sullivan *et al.*, 2003).

The Index of average percentage error (IAPE) was calculated to evaluate the precision of the age determination between the two readers (Beamish and Fournier, 1981).

According to von Bertalanffy, individual growth of a fish is the result of two phenomena: anabolism and catabolism (von Bertalanffy, 1938; Katsanevakis, 2006). The von Bertalanffy's model (1938) was chosen to describe the linear growth of the *C. conger* versus time. We retained this model because of its current use in halieutics, since its initial application by Beverton and Holt (1957), and its numerous literary references, which promoted straightforward comparisons with other populations in different geographical areas. The von Bertalanffy growth model was fitted to the observed lengths-at-age, described by the equation:

$$L_t = L_\infty (1 - e^{-K(t - t_0)})$$

where L_t is the length at time t (years), L_∞ the asymptotic length, K is a constant expressing the curvature of the growth function and t_0 is the theoretical time at which L is 0.

The von Bertalanffy growth parameters (L_∞, k, t_0) were estimated using the method reported by Ben Salem and Daget (1991).

The length-weight relationship was estimated by the power function $Wt = a\,Lt^b$ (Ricker, 1975); Wt = total weight of the fish (g), Lt = total length (mm), a = constant and b = coefficient of allometry. The regression parameters a and b were estimated for the whole population by least square linear regressions, after log transformation of both variables according to the following equation:

$$\ln (W) = \ln (a) + b \ln (Lt)$$

In = Naperian logarithm.

The nature of the allometry was determined by the comparison of the value of b to the theoretical value 3 by Student's t-test to 5%.

RESULTS

Length-weight relationship

The slope value (b = 3.37) of the length-weight relationship was significantly greater than 3.00 (t-test, $P < 0.05$), indicating positive allometric growth (Fig. 2). The value of the correlation coefficient ($R^2 > 0.9$) shows that the total mass of *C. conger* is well correlated to its size.

Age determination

Otolith sections viewed under reflected light showed alternating broad white and narrow dark rings (annuli) (Figs 3, 4).

The number of annuli on an otolith cross section indicates the age of the fish. Under reflected light and black background, a similar aspect was observed in the vertebrae (Fig. 5). Samples for which an agreement could not be reached were excluded from the data set (n = 17). The index of average percent error (IAPE) value was low (2%) and the percentage between readers was 91.2 %.

Our observations confirmed concentric growth marks on the inside surface of the vertebral cones and alternate narrow dark layers (annuli) and large white layers (zones).

Age estimates ranged from one to seven years. A linear relationship was found between the total length (Lt) and the age ($R^2 = 0.873$, $P < 0.01$; Fig. 6). The maximum number of annuli observed on any specimen was seven for a fish of 1360 mm in total length.

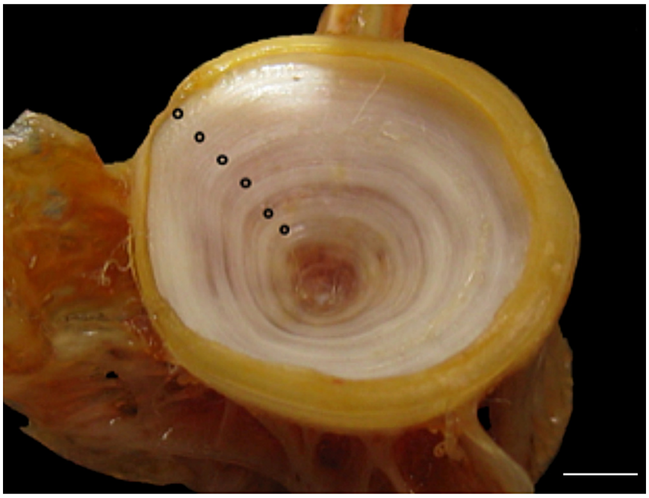

Figure 5. – Vertebra of *Conger conger* observed under a binocular microscope (×10) in reflected light (Six annuli can be seen). Scale bar = 1 cm.

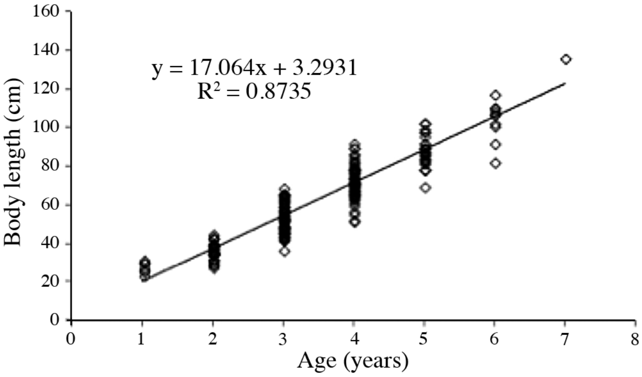

Figure 6. – Individual values and overall growth curve of *C. conger* (N = 239).

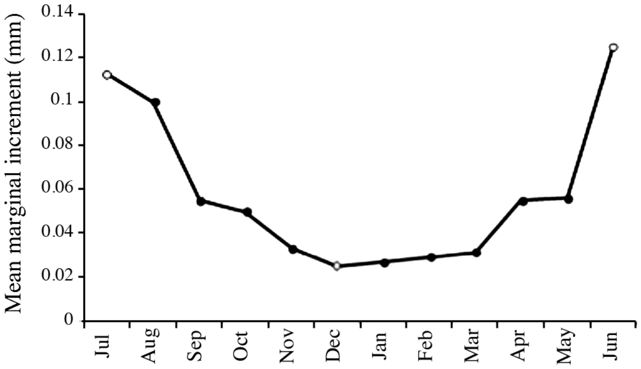

Figure 7. – Monthly mean marginal increments of otoliths for *Conger conger*.

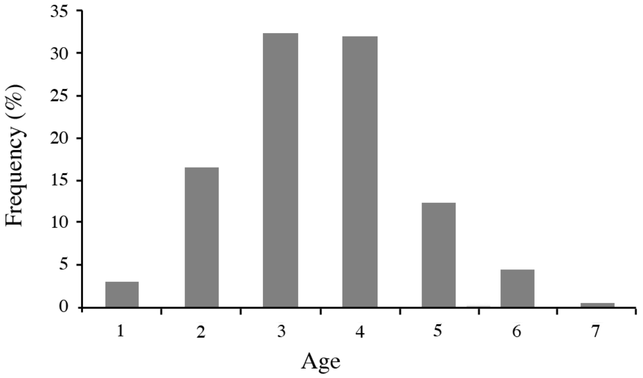

Figure 8. – Distribution of age classes for the Tunisian north coast *Conger conger*.

Validation

To validate the periodicity of the increment formation, marginal increment analysis was carried out on all otoliths.

The mean marginal increment was at its lowest value (0.025) during December (Fig. 7). The average marginal increment reached its maximum values during June (0.125) and July (0.113). These results confirm that the annuli appear in winter (December) while the zones are formed in summer (June/July). Therefore, for *C. conger* of the northern coast of Tunisia, there is one decreased growth annually. The combination of one zone and one annulus corresponds to an annual sequence of growth.

Observed age classes ranged from one to seven years. The sample studied was mostly composed of 3 and 4 year-old fish, which represented 64% of the individuals treated. Fish younger than two years and older than six years were poorly represented in the fish sample (Fig. 8). Age-length keys were established for 239 *C. conger* (Tab. I). Individuals were grouped according to the number of rings they presented, which helped to attribute a total average length to each age group.

Table I. – Age-length key for *Conger conger* from the north coast of Tunisia. SD: standard deviation; TL: total length; W: weight.

	Age (years)							
Length interval (cm)	1	2	3	4	5	6	7	Total
23.8-28.7	4							4
28.8-33.7	3	7						10
33.8-38.7		21	1					22
38.8-43.7		10	5					15
43.8-48.7		1	19					20
48.8-53.7			18					18
53.8-58.7			13	4				17
58.8-63.7			10	3				13
63.8-68.7			10	15				25
68.8-73.7			1	22	1			24
73.8-78.7				15	0			15
78.8-83.7				11	6	1		18
83.8-88.7				3	9	0		12
88.8-93.7				3	7	1		11
93.8-98.7					3	0		3
98.8-103.7					3	2		5
103.8-108.7						2		2
108.8-113.7						3		3
113.8-118.7						1		1
118.8-123.7								0
123.8-128.7								0
128.8-133.7								0
133.8-138.7							1	1
Total	7	39	77	76	29	10	1	**239**
%	2.92	16.31	32.21	31.79	12.13	4.18	0.41	**100**
Mean TL (cm)	28.00	36.36	53.50	72.51	88.33	104.18	136.00	
SD TL	2.92	4.02	7.38	8.08	7.54	10.28	0.00	
Mean W (g)	33.82	60.39	252.47	667.77	1296.54	2283.77	5000.00	
SD W	13.16	22.50	138.79	255.38	376.14	788.71	0.00	

The von Bertalanffy growth function (VBGF) for the sampled population had the following parameters:

$L_\infty = 249.032$ cm, $K = 0.118$ year^{-1} and $t_0 = 0.97$ year. The growth equation in length according to the model of von Bertalanffy is:

$$L_t = 249.032\ (1 - e^{-0.118(t-0.97)})$$

DISCUSSION

To estimate fish age directly, there are three main mineralized structures: scales, otoliths and elements of the skeleton (vertebrae, opercular) (Meunier, 1988; Panfili *et al.*, 2002), though otoliths have been the preferred option since the late 19th century (Reibish, 1899; Cunningham, 1905; Wallace, 1907; Miller, 1961; Pannella, 1971; Campana and Neilson, 1985; Jepsen *et al.*, 1999; Campana, 2001). More recently, they have been widely used to determine the age of the Congridae (Hood *et al.*, 1988; Fannon *et al.*, 1990; Sbaihi *et al.*, 2001; O'Sullivan *et al.*, 2003).

However, otoliths are often difficult to read, particularly in older fish, that is why several authors have recommended the use of other bones, such as the vertebrae (Meunier, 1988; Desse and Desse-Berset, 1992; Sbaihi *et al.*, 2001; O'Sullivan *et al.*, 2003). In fact, using the vertebrae is more reliable than using the otoliths for *C. conger* (Sbaihi *et al.*, 2001; O'Sullivan *et al.*, 2003). Especially in older specimens, the presence of multiple banding makes age determination from otoliths difficult. For *C. conger*, vertebrae are prepared and read easily.

Based on the observations of otoliths and vertebrae, we determined seven age classes for *C. conger* off the northern coast of Tunisia. Our study shows that both otoliths and vertebrae proved to be efficient structures for ageing conger eels. Moreover, vertebral bands were easily read.

In the Adriatic, the number of age classes found for this species is slightly higher: Vallisneri *et al.* (2007) and Matić-Skoko *et al.* (2012) determined eight age classes; in the Atlantic Ocean, many authors reported even a greater number of age classes; Sbaihi *et al.* (2001) determined 11 age classes for *C. conger* off the south coast of Brittany and O'Sullivan *et al.* (2003) determined 17 age classes for the same species off the Irish coast. Correia *et al.* (2009) determined 12 classes for *C. conger* off the west coast of the Iberian Peninsula using just otolithometry. The lower values of age classes for *C. conger* can be attributed to the length of *C. conger* caught in the Mediterranean Sea, ranging from 21 to 144 cm (Vallisneri *et al.*, 2007; Matić-Skoko *et al.*, 2012), while the length range of the Atlantic specimens was from 33 to 173 cm (Sbaihi *et al.*, 2001; O'Sullivan *et al.*, 2003; Correia *et al.*, 2009). Also, this finding may reflect different sampling techniques.

Validation is a necessary step for all sclerochronological studies but especially for migratory species such as *C. conger*, as there may be significant differences between populations. Validation of the periodicity of growth rings can be obtained by analysing the marginal increment (Karlou-Riga, 2000; Kerstan, 2000; Masuda *et al.*, 2000). The period of formation of growth rings of *C. conger* was estimated after calculating the marginal average elongation of the otoliths. This calculation recorded a decrease during the winter (December) in Tunisia; during this cold period, the fish confront the damaging effects of low temperatures and lack of prey. In the Adriatic Sea, marginal increment analysis showed a decrease in December and an increase in July (Matić-Skoko *et al.*, 2012). Growth parameter estimates for *C. conger* from the northern coast of Tunisia gave results of $L_\infty = 249.032$ cm, $K = 0.118$ and $t_0 = 0.97$. The comparison of growth parameter estimates of *C. conger* from different geographical areas are summarized in table II. The growth rate of the Tunisian north coast *C. conger* ($K = 0.118$) was very similar to that noted in the Adriatic Sea ($K = 0.11$, see Matić-Skoko *et al.*, 2012). This value is slightly lower than that reported for female *C. conger* of the western Algerian coast ($K = 0.23$) (Mazouz and Abi Ayad, 2015). Table II shows that the longest *C. conger* from the northern coast of Tunisia (136 cm in total length) is smaller than any recorded from the Atlantic Ocean. The maximum size of *C. conger* recorded in the Adriatic Sea (Vallisneri *et al.*, 2007; Matić-Skoko *et al.*, 2012), were 130 cm and 144 cm, respectively.

Table II. – Biogeographic comparison of von Bertalanffy growth function parameters of *C. conger*. L_∞: asymptotic length; K: growth coefficient; t_0: theoretical age at zero length; N: sample size; TL: total length; Age max: maximum age.

Auteurs	Area studied	Age determination	L_∞ (cm)	K (year)$^{-1}$	t_0 (year)	N	TL (cm)	Age max
Fannon *et al.* (1990)	Southeast coast of Irland	–	265	0.0633	–0.3861	–	–	21
O'Sullivan *et al.* (2003)	Irish coastal waters	Otoliths	271	0.037	–1.396	37	–	19
O'Sullivan *et al.* (2003)	Irish coastal waters	Vertebra	214	0.058	–1.96	166	33-159	20
Correia *et al.* (2009)	Iberian Atlantic	Otoliths	264.98	0.07	–1.2	85	38-173	12
Matić-Skoko *et al.* (2012)	Adriatic Sea	Otoliths	187.23	0.11	–0.23	284	33.2-144	8
Mazouz and Abi-Ayad (2015)	Western Algerian coasts	–	108	0.23	–0.67	male	40-115	–
Mazouz and Abi-Ayad (2015)	Western Algerian coasts	–	134	0.13	–0.69	female	40-130	–
Present study	North coast of Tunisia	Otoliths	249.032	0.118	0.97	239	2.8-136	7

Table III. – Parameters of the length-weight relationship of the *C. conger* from various geographical areas. N: sample size; b: slope; R^2: coefficient of determination, M = male, F = female.

Reference	N	Total length (cm)	Parameters of length-weight relationships			Sex	Area studied
			b	R^2	Allometry		
Cau and Manconi (1983)	104	–	3.40	0.938	–	F	South-east Sardinia
Cau and Manconi (1983)	53	–	2.59	0.813	–	M	South-east Sardinia
Sbaihi *et al.* (2001)	38	74.0-162.0	–	0.950	–	F	Coastal waters of southern Brittany
O'Sullivan *et al.* (2003)	166	33.0-159.0	3.46	0.920	–	F	Irish coastal waters
Correia *et al.* (2009)	81	38.0-173.0	3.36	0.980	Positive allometric	F	Iberian Atlantic
Matić-Skoko *et al.* (2012)	317	23.4-144.0	3.28	0.921	Positive allometric	M + F	Adriatic Sea
Mazouz and Abi-Ayad (2015)	449	40.0-130.0	3.35	0.940	Positive allometric	F	Western Algerian coast
Mazouz and Abi-Ayad (2015)	206	40.0-115.0	3.57	0.950	Positive allometric	M	Western Algerian coast
Present study	239	23.8-136.0	3.37	0.975	Positive	M + F	North coast of Tunisia

However, *C. conger* has been recorded off the Irish coast with a maximal size of 159 cm (O'Sullivan *et al.*, 2003), off the south coast of Brittany of 162 cm (Sbaihi *et al.*, 2001) and Iberian waters of 173 cm (Correia *et al.*, 2009). These differences could be due to the specific conditions of the Mediterranean Sea, such as trophic conditions. In fact, the Mediterranean Sea is considered as one of the most oligotrophic regions in the world in terms of both primary productivity and chlorophyll a concentrations (Azov, 1991).

The European conger eel (combined sex) from the north coast of Tunisia showed a positive allometric growth, with b value being significantly different from 3. Similarly, the value of b determined by Matić-Skoko *et al.* (2012) for *C. conger* (combined sex) from the Adriatic Sea was 3.28, indicating a positive allometric growth. The length-weight relationship parameters for *C. conger* from different areas obtained by various authors are given in table III. All the authors from the Mediterranean Sea and from the Atlantic Ocean reported values of b greater than 3, except Cau and Manconi (1983) in Southeast Sardinian waters where the b value for male *C. conger* was 2.59. The length-weight relationships vary according to factors such as food availability, feeding rate, gonad development and spawning period (Bagenal and Tesch, 1978).

CONCLUSION

As we found no data concerning *Conger conger* from the Tunisian north coast during our literature search, this study provides the first estimates of its age and growth parameters and contributes to a better understanding of this species. The oldest age estimate obtained was seven years. This study reports some information on the age and growth of *Conger conger* in Tunisia. This allows to a better understanding of the changes in the stock in Tunisia for a reliable stock assessment. However, as little is known about the biology of *C. conger* in the Mediterranean Sea, a more thorough knowledge of this species, especially its reproductive biology, is needed to determine a common strategy for the sustainable management of conger eel fisheries in this region.

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